Structural Organization

- classifications
  - geometry
    - line-forming
    - surface-forming
  - stiffness
    - rigid
    - flexible
  - one-way or two-way
    - spatial organization and load transfer
  - materials

Structural Components

- bearing walls
- columns
- beams
- flat plates
- trusses
- arches
- shells
- cables
Bearing Walls

• behavior as “deep beams”

Columns & Walls

Beams & Plates
Trusses and Shells

- pitched Pratt truss
- pitched Howe truss

Arches and Cables

- (c) uniform loads (horizontally) — parabolic
- (d) uniform loads (along the cable length) — catenary

Building Framing

- Components or Assemblages

- One-level system
- Two-level system
- Two-level system
- Three-level system

- Load-bearing walls
- Columns

Building Framing

- Horizontal spanning system
- Roof loads
- Decking cantilever roof loads by bending
- Decking reactions become forces on beams (which carry loads by bending)
- Beam reactions become forces on trusses
- Truss reactions cause compressive forces to develop in columns
- Columns are in compression
- Column reactions become forces on foundations (which distribute the forces into the earth)
System Selection

- evaluation of alternatives

Structural Design Criteria

- components stay together
- structure acts as whole to be stable
  - resist sliding
  - resist overturning
  - resist twisting and distortion
- internal stability
  - interconnectedness
- strength & stiffness

Structural Design Sequences

- first-order design
  - structural type and organization
  - design intent
  - contextual or programmatic
- second-order
  - structural strategies
  - material choice
  - structural systems
- third-order
  - member shaping & sizing
**Systems by Materials**

- Wood
- Steel
- Concrete
- Masonry
- Composite

**Timber Construction**

- **all-wood framing systems**
  - studs, beams, floor diaphragms, shearwalls
  - glulam arches & frames
  - post & beams
  - trusses
- **composite construction**
  - masonry shear walls
  - concrete
  - steel

**Timber Construction**

- studs, beams
- floor diaphragms & shear walls

**Timber Construction**

- glulam arches & frames
  - manufactured or custom shapes
  - glue laminated
  - bigger members
**Timber Construction**

- post & beam

- trusses

**Steel**

- cast iron – wrought iron - steel
- cables
- columns
- beams
- trusses
- frames

**Steel Construction**

- standard rolled shapes
- open web joists
- plate girders
- decking
Steel Construction

- welding
- bolts

Concrete

- columns
- beams
- slabs
- domes
- footings

Steel Construction

- fire proofing
  - cementicious spray
  - encasement in gypsum
  - intumescent – expands with heat
  - sprinkler system

Concrete Construction

- cast-in-place
- tilt-up
- prestressing
- post-tensioning
Concrete Floor Systems

- types & spanning direction

Masonry
- columns
- walls
- lintels
- beams
- arches
- footings

Grids and Patterns
- often adopted early in design
  - give order
  - cellular, ex.
- vertical and horizontal
- square and rectangular
  - single-cell
  - aggregated bays
Grids and Patterns

Systems

- total of components
- behavior of whole
- classifications
  - one-way
  - two-way
  - tubes
  - braced
  - unbraced

One-Way Systems

- horizontal vs. vertical

Two-Way Systems

- spanning system less obvious
- horizontal
  - plates
  - slabs
  - space frames
- vertical
  - columns
  - walls
Two-Way Systems

- Flat-plate system
- Flat-slab system
- Two-way beam and-slab system
- Two-way ribbed system
- Two-way ribbed system with surrounding beams

Roof Shapes

- coincide
- within

Tubes & Cores

- stiffness

Span Lengths

- crucial in selection of system
- maximum spans on charts aren’t absolute limits, but usual maximums
- increase L, increase depth$^2$ required (ex. cantilever)
- deflections depend on L
**Loading Type and Structure Type**

- **light uniform loads**
  - surface forming elements
  - those that pick up first load dictate spacing of other elements

- **heavy concentrated loads**
  - member design unique

- **distributed vs. concentrated structural strategies**
  - large beam vs. many smaller ones

**Design Issues**

- **lateral stability – all directions**

- **configuration**
Design Issues

• vertical load resistance

walls columns

Design Issues

• lateral load resistance

Design Issues

• lateral load resistance

• multi-story
  – cores, tubes, braced frames
Design Issues

• multi-story
  – avoid discontinuities
    • vertically
    • horizontally

Foundation Influence

• type may dictate fit
  – piles vs. mats vs. spread
  – capacity of soil to sustain loads
    • high capacity – smaller area of bearing needing and can spread out
    • low capacity – multiple contacts and big distribution areas

Grid Dependency on Floor Height

• wide grid = deep beams
  – increased building height
  – heavier
  – foundation design
• codes and zoning may limit
• utilize depth for mechanical

Large Spaces

• ex. auditoriums, gyms, ballrooms
• choices
  – separate two systems completely and connect along edges
  – embed in finer grid
  – staggered truss
Meeting of Grids

• common to use more than one grid
• intersection important structurally
• can use different structural materials
  – need to understand their properties
  • mechanical
  • thermal

Meeting of Grids

• horizontal choices

Other Conditions

• circulation
• building service systems
  – one-way systems have space for parallel runs
  – trusses allow for transverse penetration
  – pass beneath or interstitial floors
  • for complex or extensive services or flexibility
Other Conditions

- poking holes for member services
  - horizontal
    - need to consider area removed, where removed, and importance to shear or bending
  - vertical
    - requires framing at edges
    - can cluster openings to eliminate a bay
  - double systems

Fire Safety & Structures

- fire safety requirements can impact structural selection
- construction types
  - light
    - residential
    - wood-frame or unprotected metal
  - medium
    - masonry
  - heavy
    - protected steel or reinforced concrete

Fire Safety & Structures

- degree of occupancy hazards
- building heights
- maximum floor areas between fire wall divisions
  - can impact load bearing wall location

Fire Safety & Structures

- resistance ratings by failure type
  - transmission failure
    - fire or gasses move
  - structural failure
    - high temperatures reduce strength
    - failure when subjected to water spray
    - necessary strength

- ratings do not pertain to usefulness of structure after a fire